NISTIR 6890

Fire Resistance Determination and Performance Prediction Research Needs Workshop: Proceedings

William Grosshandler
Editor

National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

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Building and Fire Research Laboratory

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U.S. Department of Commerce
Donald L. Evans, Secretary

Technology Administration
Phillip J. Bond, Under Secretary of Commerce for Technology

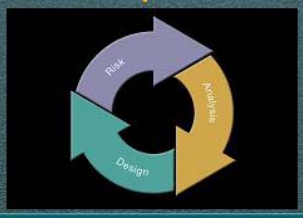
National Institute of Standards and Technology
Arden L. Bement, Jr., Director

Q. A Consultant's Wish List for a Numerical Model of Structural Response to Fire Conditions

Barbara Lane, Arup Fire
London, UK

A wish list of items to develop a numerical model for structural response to fire conditions - a consultant's view

Barbara Lane PhD
ArupFire



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Overview

- The current status - a need to establish agreed concerns?
- Components for a numerical model of structural response to fire conditions - status of current models
- The wish list...

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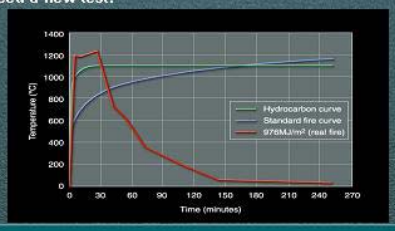
Agreed?
Concerns with the Standard Test

- Temperature / time relationship not the same as real fire behavior
- Structural response AND fire protection materials response
- But what about huge body of data existing?
- How can we (Should we??) relate this data to a numerical model for structures in fire?
- Do we need a new test?



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Agreed?
Mechanical response not addressed

- Single elements tested
- In general single elements "analyzed"
- So real frame behavior ignored
- For example:
  - Effects of restrained thermal expansion
  - Load transfer through connections to cooler elements
  - Slab action identified in the Cardington tests as key to increase in overall strength of composite frames in fire
- But what about other assemblies - non Cardington frames?
- Single element analysis cannot capture these responses - is this the case?
- Current FE modeling techniques just beginning to capture complex responses - but not part of "mainstream" design work

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Advanced Calculation Models

- In Europe principles laid out in, for example:
  - Eurocode 3 Part 1.2 Structural fire design
  - CIB W014 Rational Fire Safety Engineering Approach to Fire Resistance in Buildings
- In USA:
  - Subject of AISC work, ASCE/SFPE work, new NIST program of work

Information required:

Reference document for consultants, authorities having jurisdiction etc

Stating design objectives, means of achieving acceptable results

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Summary of Advanced Method

1. Thermal Action/Design Fire

Do we:

Create new standard fire resistance test?

Use temperature-time relationships from real fire data?

Use Natural/Real fire calculation: fire load, ventilation, boundary properties etc?

Information required:

Clear guidance on design basis fires

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Summary of Advanced Method

2. Thermal Response

Using defined design fire, calculate heat transfer to structural elements

Results in a temperature field in each structural element

Information required:

Have existing heat transfer models been assessed?

Do we need new heat transfer model for current construction materials?

To what detail do we need a temperature profile along the length and through the cross-section of each structural element?

How do we assess protected structural elements?

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Summary of Advanced Method

3. Mechanical Response, as a result of design fire

Structural elements losing strength and stiffness

Restraint to thermal expansion produces compression forces

Higher restraint leads to greater deflections

Through depth thermal gradients imposing curvature (bowing)

Combinations of thermal expansion, bowing and restraint conditions can produce large range of deflection and internal force patterns

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Summary of Advanced Method

3. Mechanical Response, as a result of design fire

Information required:

What model captures these effects for all construction assemblies?

Is there a means of carrying out a single element analysis that summarises these effects?

Can these models be translated into simple tables for mainstream design?

How can we incorporate the new understanding and future understanding into existing building codes?

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Existing Numerical Models

It is not simple

Intensive work for 10 years in Europe only starting to make progress now

Essential to build on this work rather than start again

Not in format at this time that is useful in a design office

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Status of current models

- Vulcan - University of Sheffield
- Composite steel framed buildings only
- Validated using Cardington results
- Geometric and material nonlinearities included
- Plate elements used to simulate floor slabs
- Stress resultant issues?
- Shear connectors incorporated using?
- Beam-column element to simulate beams and columns
- Spring elements to simulate steel-to-steel connections
- Reinforcement modelled?
- Heat transfer analysis not part of Vulcan - data incorporated from other sources
- Temperature non-uniform through cross-section but not along length for steel? Same for concrete??
- Implicit analysis

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Status of current models

- ABAQUS - University of Edinburgh
- Composite steel framed buildings only
- Validated using Cardington results
- Geometric and material nonlinearities included
- Shell elements used to simulate floor slabs
- Stress resultant approach to describe behaviour of shells
- Shear connectors incorporated using rigid elements
- Beam-column element to simulate beams and columns??
- Pins used to model steel-to-steel connections
- Reinforcement included in slab as a smeared model
- Heat transfer analysis part of ABAQUS but not used by Edinburgh - Eurocode for Steel, HADAPT for concrete
- Temperature non-uniform through cross-section but not along length for steel
- Linear through depth gradient assumed for slab heating??
- Implicit analysis. ABAQUS explicit now exists

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Status of current models

- SAFIR, CTICM models should also be reviewed
- What about explicit models such as LS - DYNA?
- Each elements solved individually - can assess collapse even when some components no longer have stiffness
- Can cope with highly non-linear problems
- More computing power and time required
- Thermal analysis possible in parallel with mechanical analysis

Information required:
Capability of each model to date - what it can and cannot do, what aspects of each model holds the advantage?

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This wish list....

- Agree concerns/issues/inaccuracies
- A reference document laying out acceptable principles required for AHJ, consultants etc
- Establish design fire - criteria/data/model/input for codes
- Establish heat transfer analysis capabilities
- Compare and contrast existing 3D FE models
- Further develop these models to address complex behaviours associated with structural response to fire - not just Cardington type frame, not just office fire load, etc
- Develop commercially possible analysis tools - is it possible to reduce time/complexity of analysis once further understanding obtained?
- Develop means of translating results into quantifiable results for Building Codes, into simple design methods

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